Groundwater Investigation and Remediation

CHAPTER 8

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During 2005, groundwater investigations and remediation activities performed under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) continued at both the Livermore site and Site 300. LLNL collects and analyzes groundwater, soil, and soil vapor samples from areas of known or suspected contamination. Portions of the two sites where soil or groundwater contains or may contain chemicals of concern are actively investigated to define the hydrogeology, nature and extent of the contamination, and source areas. Where necessary, remediation strategies are developed and evaluated in preparation for a CERCLA removal action or through the feasibility study process. An approved remedy for each area is developed in consultation with the regulatory agencies and the community.

This chapter reviews the distribution of contaminants and LLNL's progress in removing contaminants from groundwater and from the unsaturated zone (soil vapor) at the Livermore site and Site 300. Contamination for the most part is confined to each site. Site 300, with an area of 28.3 km^2 (10.9 mi^2) has been divided into eight operable units based on the nature and extent of contamination and on topographic and hydrologic considerations. The Livermore site at 3.3 km^2 (1.3 mi^2) is effectively one operable unit.

Livermore Site Ground Water Project

Initial releases of hazardous materials occurred at the Livermore site in the mid-to-late 1940s when the site was the Livermore Naval Air Station (Thorpe et al. 1990). There is also evidence that localized spills, leaking tanks and impoundments, and landfills contributed volatile organic compounds (VOCs), fuel hydrocarbons, metals, and tritium to the groundwater and unsaturated zone in the post-Navy era. The Livermore site was placed on the U.S. Environmental Protection Agency National Priorities List in 1987.

An analysis of all environmental media showed that groundwater and both saturated and unsaturated sediments are the only media that require remediation (Thorpe et al. 1990). The identified compounds that currently exist in groundwater at various locations beneath the site at concentrations above drinking water standards (maximum contaminant levels [MCLs]), are trichloroethylene (TCE), perchloroethylene (PCE), 1,1-dichloroethylene, chloroform, 1, 2-dichloroethylene, 1,1-dichloroethane, 1,2-dichloroethane, trichlorotrifluoroethane (Freon 113), trichlorofluoromethane (Freon 11), and carbon tetrachloride. PCE is also present at low concentrations above the MCL in several offsite plumes that extend from the southwestern corner of the Livermore site. LLNL operates groundwater extraction wells in this area. In addition, LLNL maintains an extensive network of monitoring wells in the offsite area west of Vasco Road.

Physiographic Setting

The general topography of the Livermore site is described in Chapter 1. The Livermore Valley groundwater system consists of several semiconfined aquifers. Rainfall from the surrounding hills recharges the groundwater system, which flows toward the east-west axis of the valley. Along the southwest portion of the Livermore Valley, the direction of groundwater flow changes from east-west to south and into the Sunol Valley Groundwater Basin.

The thickest sediments and aquifers are present in the central and western portions of the Livermore Valley, where they form an important resource for the Zone 7 Water Agency. These sediments comprise two aquifers: the Livermore Formation and overlying alluvium. The Livermore Formation averages about 1000 m in thickness and occupies an area of approximately 250 km^2. The alluvium, which is about 100 m thick, is the principal water-producing aquifer within the valley.

Hydrogeology of the Livermore Site

Sediments at the Livermore site are grouped into four grain-size categories—clay, silt, sand, and gravel. Groundwater flow beneath the site occurs primarily in alluvial sand and gravel deposits, which are bounded by the less permeable clay and silt deposits. The alluvial sediments have been subdivided into nine hydrostratigraphic units (HSUs) beneath the Livermore site (see **Figure 8-1**). HSUs are defined as sedimentary sequences whose permeable layers show evidence of being hydraulically interconnected. Six of the nine HSUs contain contaminants at concentrations above their MCLs: HSUs 1B, 2, 3A, 3B, 4, and 5 (Blake et al. 1995; Hoffman et al. 2003). HSUs 1A, 6, and 7, on the other hand, do not contain contaminants of concern above action levels and are therefore not discussed further.

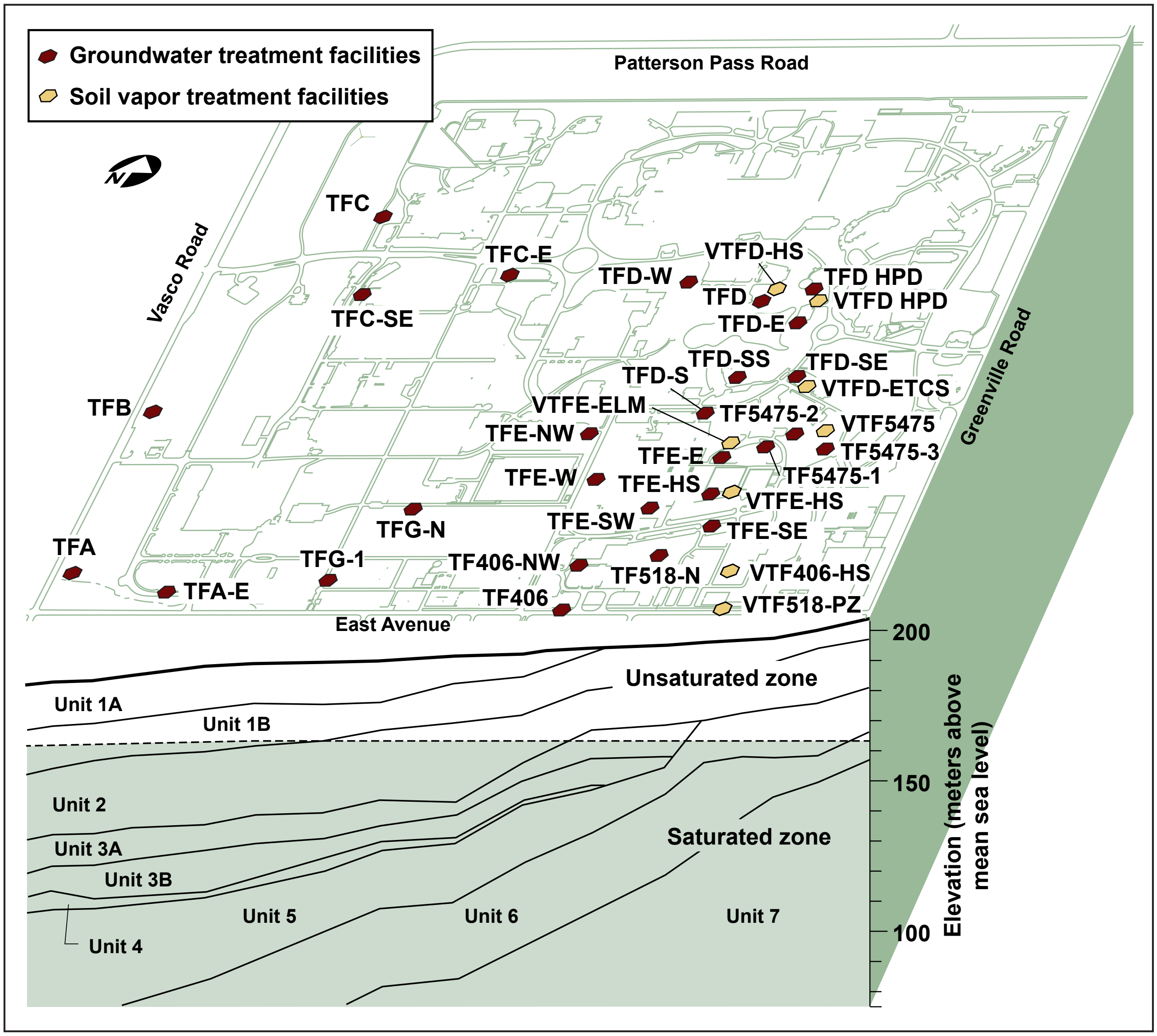


Figure 8-1. Map and cross section of the Livermore site showing hydrostratigraphic units and the locations of the treatment facilities

Remediation Activities and Monitoring Results

This section summarizes the primary activities and results of the Livermore site Ground Water Project in 2005. Additional information is provided in the *Ground Water Project 2005 Annual Report* (Karachewski et al. 2006). In addition to discussing trends during the past year, this section also highlights the significant reduction of VOC concentrations at LLNL during the past five years.

In 2005, LLNL operated 27 groundwater treatment facilities in the TFA, TFB, TFC, TFD, TFE, TFG, and TFH (TF406, TF518, and TF5475) areas (see **Figure 8-1**). The 77 groundwater extraction wells and 22 dual extraction wells produced more than 1129 million liters of groundwater and the treatment facilities removed more than 71 kg of VOCs (**Table 8-1**) from this volume. For comparison, in 2004 the groundwater treatment facilities removed approximately 86 kg of VOCs. The lower quantity of mass removed in 2005 is partially due to decreasing concentrations in the TFD and TFE source areas and declining extraction well flow rates due to remediation-induced dewatering at the site. Since remediation began in 1989, more than 10,700 million liters of groundwater have been treated, resulting in removal of more than 1168 kg of VOCs.

Table 8-1. Volatile organic compounds removed from groundwater and soil at the Livermore site

Treatment facility area[a]	2005		Cumulative total	
Groundwater	**Water treated (ML)[b]**	**VOCs removed (kg)**	**Water treated (ML)**	**VOCs removed (kg)**
TFA	418.1	6.9	4,927.3	178.6
TFB	111.6	3.2	1,122.6	65.7
TFC	138.7	5.8	964.1	71.9
TFD	287.0	42.7	2,367.3	649.8
TFE	99.8	9.9	848.2	172.4
TFG	27.6	1.2	142.6	7.2
TFH	45.9	1.5	405.1	22.6
Total[c]	1,129	71	10,777	1,168
Soil vapor[d]	**Soil vapor treated ($10^3 m^3$)**	**VOCs removed (kg)**	**Soil vapor treated ($10^3 m^3$)**	**VOCs removed (kg)**
TFD	444.3	58.4	595.7	66.0
TFE	1,096.9	27.4	1,875.0	123.0
TFH	804.3	110.5	2,492.7	722.2
Total[c]	2,346	196	4,963	911

a Treatment areas and facilities:
TFA area: TFA, TFA-E
TFB area: TFB
TFC area: TFC, TFC-E, TFC-SE
TFD area: TFD, TFD-E, TFD-HPD, TFD-S, TFD-SE, TFD-SS, TFD-W, VTFD-ETCS, VTFD-HPD, VTFD-HS
TFE area: TFE-E, TFE-HS, TFE-NW, TFE-SE, TFE-SW, TFE-W, VTFE-ELM, VTFE-HS
TFG area: TFG-1, TFG-N
TFH area: TF406, TF406-NW, VTF406-HS, TF518-N, VTF518-PZ, TF5475-1, TF5475-2, TF5475-3, VTF5475

b ML = million liters

c Totals rounded to nearest whole number

d Includes only those treatment areas at which vapor was extracted.

In 2005, LLNL also operated eight soil vapor treatment facilities: VTFD East Traffic Circle South (VTFD-ETCS), VTFD Helipad (VTFD-HPD), VTFD Hotspot (VTFD-HS), VTFE Eastern Landing Mat (VTFE-ELM), VTFE Hotspot (VTFE-HS), VTF406 Hotspot (VTF406-HS), VTF518 Perched Zone (VTF518-PZ), and VTF5475 (see **Figure 8-1**). The 20 soil vapor extraction wells and 22 dual extraction wells produced more than 2.3 million cubic meters of soil vapor and the treatment facilities removed more than 196 kg of VOCs (**Table 8-1**). In 2004, the soil vapor treatment facilities removed approximately 133 kg of VOCs. The significantly higher rate of mass removal in 2005 (a 47% increase) is due to activation of new vapor treatment facilities VTFD-ETCS, VTFD-HS, VTFE-HS, and VTF406-HS. Since initial operation, about 5 million cubic meters of soil vapor has been extracted and treated, removing more than 911 kg of VOCs from the subsurface.

The *Ground Water Project 2005 Annual Report* (Karachewski et al. 2006) includes additional information, including regulatory compliance, field investigations, and a summary of the remedial action program.

Over the last five years, groundwater VOC concentrations in HSUs 1B, 2, and 3A along the western and southern margins of the Livermore site have continued to decline, particularly in the offsite areas, due to the combined effects of hydraulic capture and groundwater treatment. The concentration decline in HSU-2 over the last five years is shown in **Figure 8-2**. Within the interior of the site, aggressive implementation of pump and treat remediation using portable treatment units positioned downgradient of source areas has resulted in concentration declines in HSUs 2, 3A, 3B, 4, and 5.

Over the last three years, remediation activities, including soil vapor extraction, dual extraction, and groundwater extraction, have focused primarily on source area cleanup. **Figure 8-3** shows the increasing amount of mass removed in response to these cleanup activities.

In 2005, concentrations continued to decrease in most Livermore site VOC plumes. The decline in VOC concentrations is primarily attributed to active remediation and reflects the removal of more than 267 kg of VOCs by the groundwater and soil vapor extraction wells during the year. Notable trends and results are discussed below.

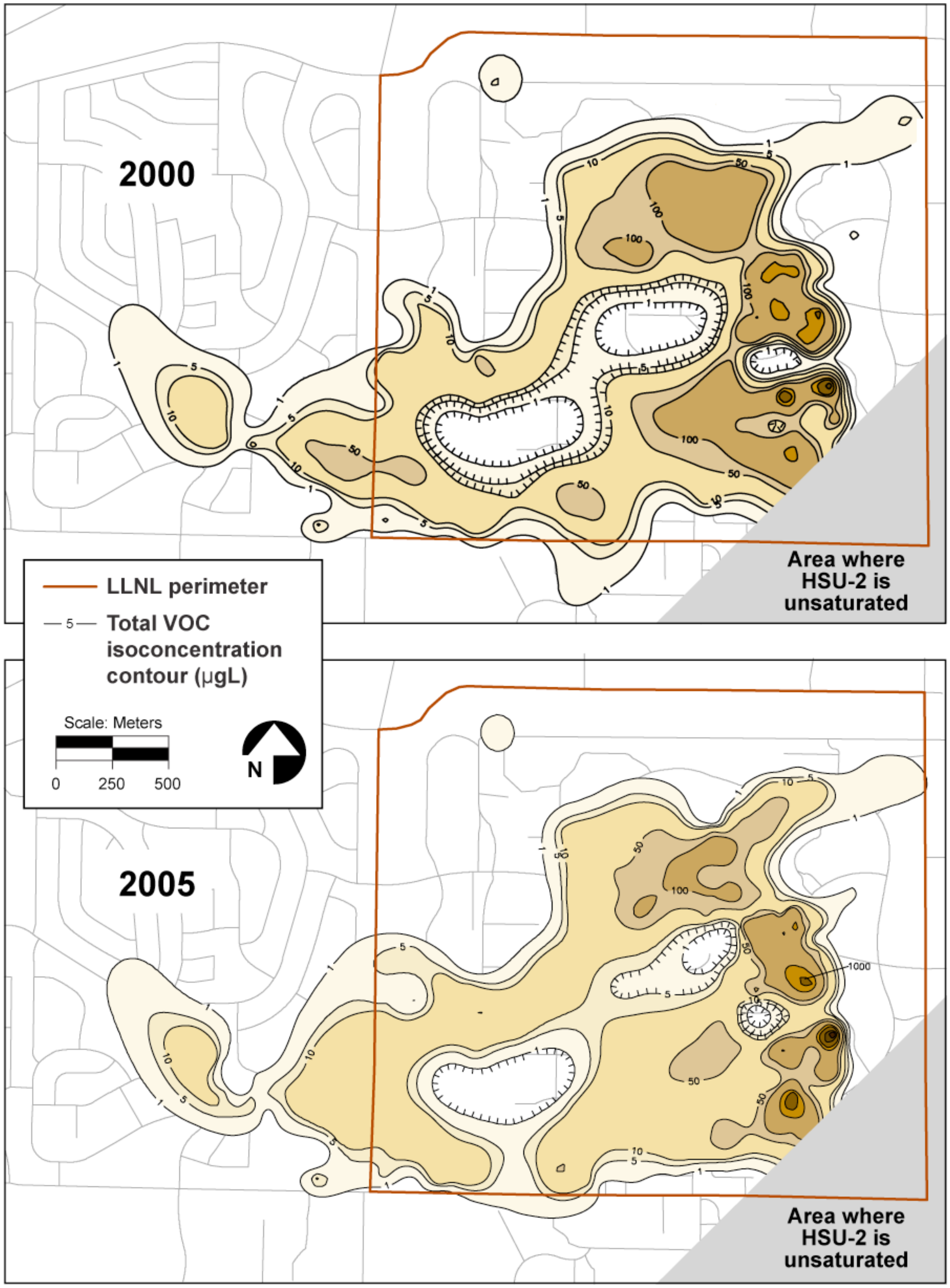


Figure 8-2. Isoconcentration maps showing reductions in total VOC concentrations for HSU-2 between 2000 and 2005

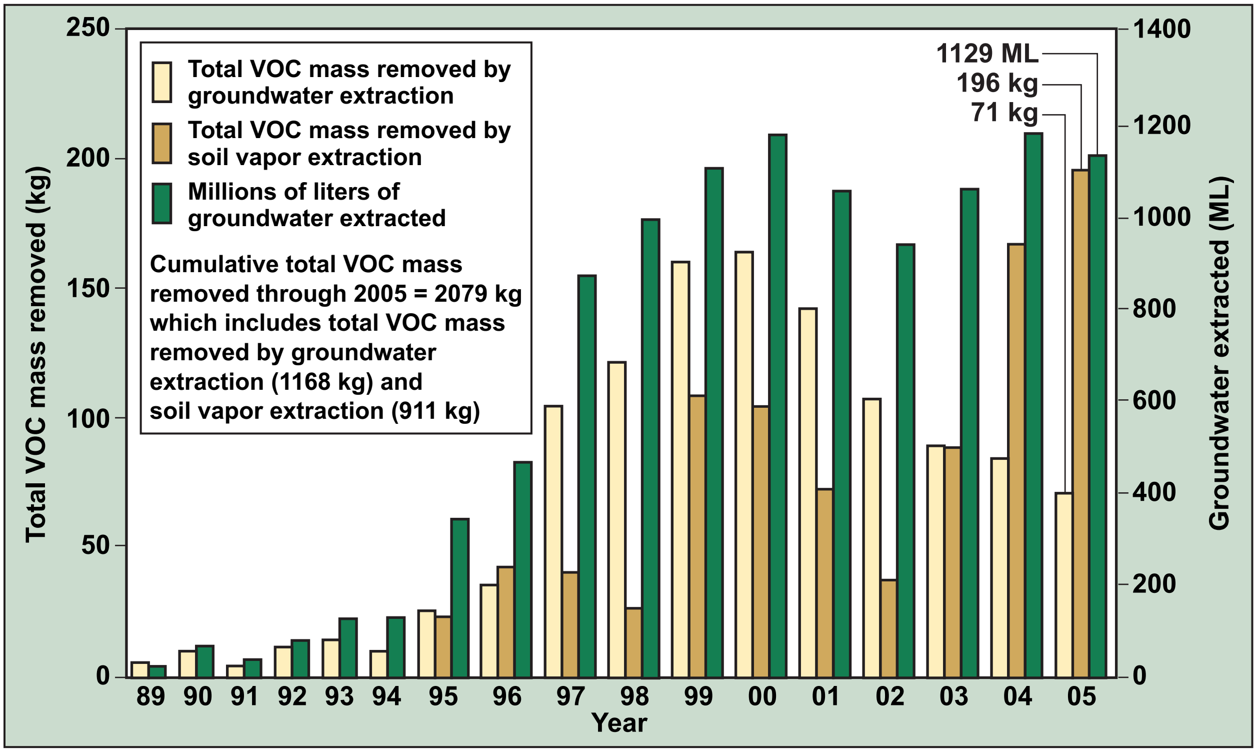


Figure 8-3. Total VOC mass removed and volume of groundwater extracted from the subsurface of the Livermore site, 1989–2005

VOC concentrations on the western margin of the site generally continued to decline gradually, indicating continued effective hydraulic control of the boundary plumes in the TFA, TFB, and TFC areas. The off-site HSU-1B VOC plumes were below MCLs except at one well, where a slight decrease in PCE concentration (from 11 ppb in July 2004 to 9.7 ppb at well W-1425 in August 2005) was observed. The entire offsite and onsite TFA HSU-2 total VOC plume remained below 50 ppb. The highest PCE levels offsite remain at wells W-404 and W-654, where third quarter 2005 concentrations were 20 ppb and 13 ppb, respectively. All TFA, TFB, and TFC source areas remained unchanged, except at the TFC Hotspot area. Concentrations of TCE in this area increased from 170 ppb (October, 2004) to 260 ppb (October 2005) in HSU-1B piezometer SIP-501-007. Groundwater remediation is scheduled to begin in this area during fiscal year (FY) 2006 as part of the TFC Hotspot Remedial Action Implementation Plan (RAIP) milestone.

VOC concentrations in a mobile HSU-2 plume located in the western TFE area continue to decline (see Figure 8-2). Downgradient from the source area, total VOC concentrations decreased below 100 ppb in TFE-W extraction well W-305. Total VOCs in piezometer SIP-331-001, located in the distal part of the plume, declined from 69 ppb in March 2004 to 36 ppb in June 2005 due to continued groundwater extraction at the TFE West treatment facility. Concentrations in the VOC source area at the Eastern Landing Mat have remained relatively constant over the last two years (210 ppb TCE at extraction well W-1109 in July 2005).

PCE and TCE appeared in TFB HSU-3A well W-310 for the first time (3.5 ppb, and 1.3 ppb, respectively) in November 2004. Testing is planned to determine whether these VOCs represent the leading edge of an HSU-3A plume emanating from the TFD area or are due to faulty well completion. Total VOC concentrations in TFD Helipad HSU-3A source area extraction wells continued to decline, in part due to vacuum-enhanced groundwater extraction. For example, the VOC concentrations in well W-1657 declined from 884 ppb in July 2004 to 502 ppb in August 2005. A large concentration decline was observed in the Trailer 5425 area, where total VOCs in well W-206 were 1651 ppb in July 2004 and 378 ppb in August 2005. Farther downgradient to the southwest at well W-1201, total VOC concentrations increased from 230 ppb in August 2004 to 375 ppb in August 2005. These changes may be due in part to groundwater extraction at the TFE Hotspot (well W-2012), which began operation in 2005. Elsewhere in HSU-3A, VOC concentrations remained largely unchanged.

VOC concentrations in HSU-3B and HSU-5 remained largely unchanged during 2005. Concentrations in HSU-4 also remained relatively unchanged except for well W-351 in the TFD area, where TCE concentrations decreased from 470 ppb in July 2004 to 120 ppb in October 2005. This decrease may be due to groundwater extraction at the TFD Helipad (well W-1254), which began operation in June 2004. Concentrations continued to decline in HSU-5 on Sandia/California property in the TF406 South area, with only TCE remaining above MCLs in two offsite wells (10 ppb in well W-509 and 5.6 ppb in well W-1113 in October 2005). The ongoing cleanup at the TF406 South location indicates that construction of a new facility is not warranted at this time. Accordingly, a revised schedule of remedial actions was signed by the Remedial Project Managers on October 11, 2005, removing the TF406 South facility as an FY 2006 milestone.

During 2005, tritium activities in groundwater from all wells at the Livermore site, including those in the Trailer 5475 and Building 292 areas, were below the 20,000 pCi/L MCL and continued to decrease by natural decay.

Groundwater Flow and Transport Modeling

Groundwater flow and contaminant transport models are used at the Livermore site to optimize the design and operation of remediation systems; to support ongoing subsurface characterization activities; and to improve the ability to forecast, monitor, and interpret the progress of the remediation program. In addition, site-specific models are developed to assess the potential impact to groundwater from residual contamination in sediments above the water table.

In 2005, ERD continued development and utilization of a comprehensive basin-scale groundwater flow and transport model to simulate all relevant subsurface hydrologic processes influencing contaminant transport at the Livermore site. The model is currently applied to improve the remediation efficiency for the distal plumes west of the site. This model will also be applied to better understand dewatering processes observed at the eastern portion of the site, predict the vertical migration of VOCs between adjacent HSUs, and incorporate the long-term impact of source areas where high concentrations of VOCs remain in low permeability sediments.

The model results are used by hydrogeologists to make decisions on where to place new extraction wells and how to adjust the extraction flow rates in existing wells to ensure complete capture of the VOC contamination in groundwater as well as to reduce the cleanup time and cost of remediation.

Environmental Impacts

At the Livermore site, LLNL strives to reduce risks arising from chemicals released to the environment and to conduct all its restoration activities to protect environmental resources and to preserve the health and safety of all site workers. LLNL's Environmental Restoration project is committed to preventing present day and future human exposure to contaminated soil and groundwater, preventing further contaminant migration of concentrations above drinking water standards, reducing concentrations in groundwater, and minimizing contaminant migration from the unsaturated zone to the underlying groundwater.

Remedial solutions are implemented that have been determined to be most appropriate for individual areas of contamination. The selected remedial solutions have been agreed upon by DOE and the regulatory agencies with public input and are designed to achieve the goals of reducing risks to human health and the environment and satisfying remediation objectives, regulatory standards for chemicals in water and soil, and other state and federal requirements. These remedial solutions include groundwater extraction and treatment, soil vapor extraction and treatment, or a combination of both.

Groundwater and soil vapor extraction and treatment at the Livermore site continue to reduce the mass of contaminants in the subsurface. A graph of VOC mass removed at the Livermore site since 1989 is presented in **Figure 8-3**. In 2005, the groundwater and soil vapor treatment facilities removed more than 267 kg of VOCs. Since remediation efforts began in 1989, more than 10,700 million liters of groundwater and approximately 4.9 million m^3 of soil vapor have been treated, yielding a total of more than 2079 kg of removed VOCs.

Site 300 CERCLA Project

Environmental investigations and cleanup activities at Site 300 began in 1981. Site 300 became a CERCLA site in 1990, when it was placed on the National Priorities List. The CERCLA environmental restoration operable units (OUs) and groundwater contaminant plumes are shown in **Figure 8-4**. All characterized contaminant release sites have been assigned to one of eight OUs based on the nature, extent, and sources of contamination, and

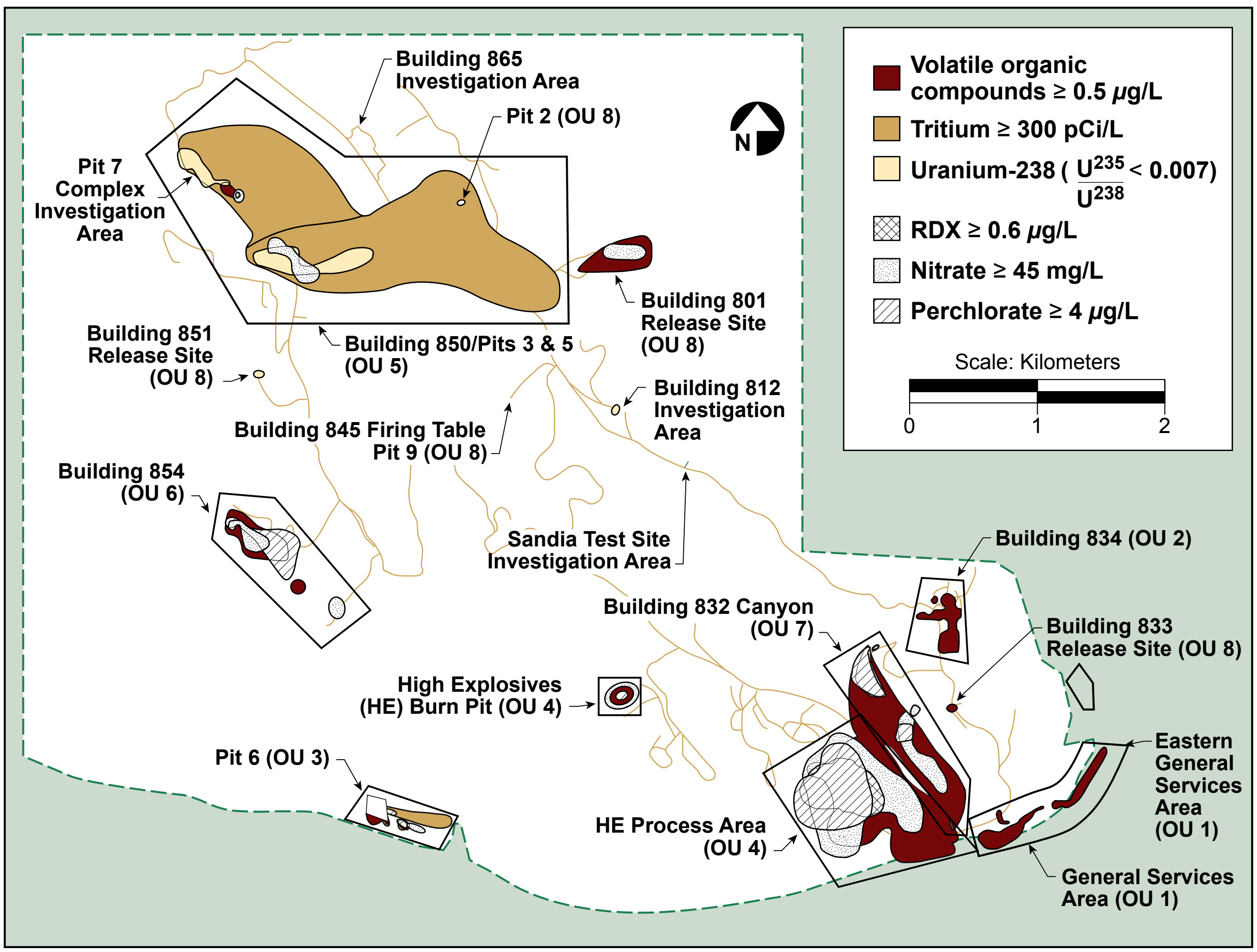


Figure 8-4. Environmental restoration operable units, investigation areas, and contaminants of concern

topographic and hydrologic considerations. The major contaminants of concern for each OU are listed in **Table 8-2**. CERCLA work at Site 300 is conducted under a Federal Facility Agreement (FFA) and other requirements. Background information for LLNL environmental characterization and restoration activities at Site 300 can be found in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994). Key milestone and deliverable due dates for 2005 are listed in **Table 8-3**. All milestone and deliverable due dates were met during 2005.

Table 8-2. Major contaminants of concern found in soil, rock, and groundwater at Site 300

Operable Unit (OU)	Contaminant of concern[a]
General Services Area (GSA) (OU1)	VOCs (primarily TCE)
Building 834 Complex (OU2)	VOCs (primarily TCE), organosilicate oil, nitrate
Pit 6 (OU3)	VOCs (primarily TCE), tritium, nitrate, perchlorate
Explosives Process Area (OU4)	VOCs (primarily TCE), HE (primarily RDX), nitrate, perchlorate
Building 850/Pits 3 & 5 (OU5)	Tritium, depleted uranium, VOCs (primarily TCE), nitrate, perchlorate
Building 854 (OU6)	VOCs (primarily TCE), nitrate, perchlorate
Building 832 Canyon (OU7)	VOCs (primarily TCE), nitrate, perchlorate
Site-Wide Operable Unit (OU8)	VOCs (primarily TCE and Freon 113), nitrate, perchlorate, depleted uranium, tritium, metals, RDX

a See Acronyms and Abbreviations for list of acronyms.

Table 8-3. Calendar year 2005 deliverable and milestone dates for Site 300 environmental restoration activities outlined in the FFA and other agreements

Deliverable/Milestone[a]	Due Date
Final Remedial Investigation/Feasibility Study (RI/FS) for the Pit 7 Complex	June 27 (met)
Draft Interim Remedial Design Report for the Building 832 Canyon OU	September 9 (met)
Characterization Summary Report for the Building 812 Study Area	September 30 (met)
Install monitor wells for Building 865	September 30 (met)
Expand B832-SRC groundwater extraction wellfield in the Building 832 Canyon OU	September 30 (met)
Conduct surface soil sampling at Sandia Test Site	September 30 (met)
Construct B829-SRC groundwater extraction and treatment facility in HE Process Area OU	September 30 (met)
Construct B817-PRX groundwater extraction and treatment facility in HE Process Area OU	September 30 (met)
Draft Proposed Plan for the Pit 7 Complex	October 6 (met)
Characterization Summary Report for the Sandia Test Site	December 15 (met)

a See Acronyms and Abbreviations for list of acronyms.

Physiographic Setting and Geology of Site 300

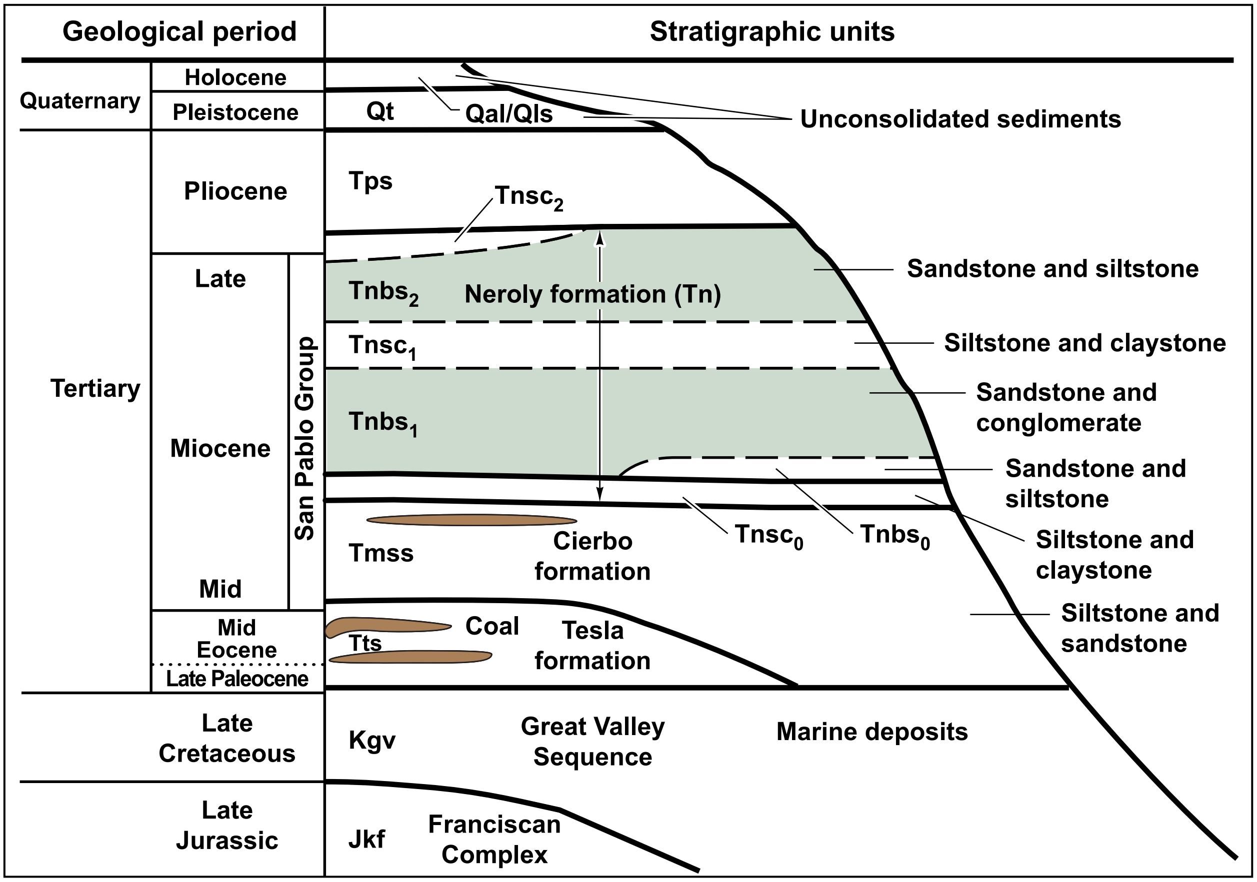
Site 300 is located in the sparsely populated Altamont Hills, which are part of the Coast Ranges Physiographic Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. Site 300 stratigraphy is shown in **Figure 8-5**. Rocks exposed in the region are classified into three groups:

- Late Tertiary-Quaternary (0–5 million years ago)—alluvium and semi-lithified sediments, mainly of continental origin
- Early to late Tertiary (5–65 million years ago)—shallow marine and continental sedimentary and volcaniclastic rocks
- Jurassic-Cretaceous (65–180 million years ago)—Great Valley sequence (marine sedimentary rocks and ophiolites) and Franciscan Complex (sheared and variably metamorphosed sedimentary and igneous rocks)

Distinctive blue-gray to brown weathering volcaniclastic sandstone and sandy siltstone, interbedded with light gray weathering tuffaceous claystone and conglomerate, are exposed extensively within Site 300. These rocks are mapped as the late Miocene Neroly Formation (Huey 1948; Dibblee 1980). The Neroly Formation is also present in the subsurface beneath Site 300. It contains the principal hydrostratigraphic units (HSUs) within Site 300 and has been the focus of the detailed geologic and hydrogeologic studies conducted during recent years (summarized in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, [Webster-Scholten 1994]). The complete section of the Neroly Formation is about 150 m thick beneath Site 300.

The floodplain of Corral Hollow Creek lies along the southern boundary of Site 300 and borders portions of the General Services Area (GSA), the Explosives Process Area, and the area of closed landfill Pit 6. Floodplain alluvium consists dominantly of coarse cobble-bearing terrace gravel derived from sources to the south, with lenses and local coverings of sandy silt and silty clay.

The bedrock sequence within Site 300 has been offset by regional faults and slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional faults and fracture patterns, locally influence groundwater flow within the site and have therefore been studied in great detail as part of the CERCLA investigations.



Hydrologic characteristics of stratigraphic units:

Quaternary alluvium and underlying decomposed bedrock (Qal/WBR): Occurs in ravines and valley bottoms throughout Site 300. It is perennially saturated beneath Corral Hollow Creek, in Doall Ravine, and in southern Elk Ravine in the vicinity of Building 812. Groundwater also occurs in Qal/WBR in the Pit 7 Complex during the winter rainy season or during extended periods of higher than normal rainfall. Groundwater in this unit is unconfined.

Quaternary landslide deposits (Qls): Thin zones of unconfined groundwater occur locally beneath the Building 851 and Building 854 areas.

Quaternary terrace alluvium (Qt): Present and saturated at Pit 6, the GSA, and the Building 832 Canyon area; some of the groundwater occurrences are ephemeral.

Pliocene non-marine sediments (Tps/Tpsg): Saturated in the Building 833 and 834 areas and the Explosives Process area. This bedrock unit is generally present only on hilltops. Where present, groundwater is typically unconfined, perched, discontinuous, and ephemeral. The exception to this condition exists in the Explosives Process Area, where the extent of saturation is significant.

Neroly Formation (Tn): Most extensive and saturated bedrock strata beneath Site 300. Unconfined to artesian conditions may exist. The formation is subdivided into the following units:

- **Upper claystone/siltstone unit ($Tnsc_2$):** Absent beneath much of Site 300. Saturated beneath the Building 834 area.
- **Upper blue sandstone unit ($Tnbs_2$):** Absent beneath much of Site 300. Saturated beneath Explosives Process Area.
- **Lower siltstone/claystone unit ($Tnsc_1$):** Saturated beneath Explosives Process Area, Building 832 Canyon.
- **Lower blue sandstone unit of the Neroly formation. ($Tnbs_1$):** Primary water-bearing strata within the Neroly Formation. Saturated throughout Site 300, except in northeast portion, where it is absent. Fine-grained siltstone and claystone interbeds act as aquitards, confining layers, or perching horizons.
- **Basal sandstone unit ($Tnbs_0$):** Saturated beneath the Pit 7 Complex, Pit 2, and Building 801/Pit 8 areas.
- **Basal siltstone/claystone unit ($Tnsc_0$)**: Saturated beneath the Building 854 area, Building 845/Pit 9.

Cierbo Formation (Tmss): Groundwater occurs beneath Doall Ravine, the Building 850, 851, and 854 areas and the East Firing Area. The continuity of saturation between the northwest and southeast areas of Site 300 is undetermined. Groundwater occurs under unconfined to artesian conditions. Where saturation does not occur, fine-grained siltstone and claystone interbeds may act as aquitards, confining layers, or perching horizons.

Tesla formation (Tts): Only found to contain groundwater immediately south of the Site 300 Pit 6 area.

Great Valley Sequence (Kgv): Groundwater not found in the few wells at Site 300 that penetrate the upper portion of the Great Valley Sequence.

Franciscan Complex (Jkf): No wells at Site 300 penetrate the Franciscan Complex.

Figure 8-5. Site 300 stratigraphy

Hydrogeology of Site 300

All groundwater contaminant plumes at Site 300 occur in Neroly Formation (Tn) rocks, unnamed Pliocene nonmarine sediments (Tps), or unconsolidated Quaternary sediment and weathered bedrock (Qal/WBR, Qls, or Qt) stratigraphic units. The extent of groundwater contamination at Site 300 is shown in **Figure 8-4**. The hydrogeology of Site 300 is described in more detail in Chapter 1. Within Site 300, groundwater-bearing strata have been grouped into hydrostratigraphic units that underlie various portions of Site 300. Contamination within these HSUs is decribed in the following section.

Remediation Activities and Monitoring Results

This section presents a summary of monitoring and remediation results for contaminant release sites at Site 300. Detailed monitoring and remediation results for the GSA, Building 834, Explosives Process Area, Building 850, Building 854, Pit 6, Building 832 Canyon, and Site-Wide OUs are presented in the Compliance Monitoring Program (CMP) reports for Site 300 (Dibley et al. 2005, 2006). The 2005 Annual CMP Report (Dibley et al. 2006) is included on the report CD. The *Site-Wide Remediation Evaluation Summary Report* (SWESR, Ferry et al. 2006) provides a comprehensive analysis of progress in achieving remedial action objectives at the contaminant release sites over the last five years. The Eastern GSA was not previously included in the CMP report, as it operated under a separate waste discharge requirements permit. Results for the first half of 2005 were presented both in two quarterly reports (Yow 2005a,b) and in the annual CMP report; in the future these results will be presented only in CMP reports. The results of investigations at the Pit 7 Complex, Building 865, Building 812, and Sandia Test Site are not included in the CMP and SWESR reports. Current information for each of these portions of Site 300 is presented at the end of this section.

At Site 300, there are 16 groundwater extraction and treatment facilities. During 2005, twelve of these facilities treated groundwater while four facilities treated soil vapor and groundwater. Twenty-five wells that extract only groundwater, 7 wells that extract only soil vapor, and 24 wells that extract both groundwater and soil vapor were pumped and the groundwater and soil vapor were fed into treatment systems during 2005. In 2005, the 25 wells that extract only groundwater and the 24 wells that extract both groundwater and soil vapor yielded 100.4 million L of groundwater. During the year, the 24 wells that extract both vapor and groundwater and the 7 wells that extract only vapor removed 1111 million m^3 of vapor. In 2005, the Site 300 treatment facilities removed 89.7 kg of VOCs, 0.09 kg of perchlorate, 739.7 kg of nitrate, 0.09 kg of RDX high explosive compound, and 0.41 kg of organic silicate oil. Since groundwater and vapor remediation efforts began in 1990, more than 1176 million liters of groundwater and 5281 million m^3 of vapor have been treated, to yield about 379.9 kg of removed VOCs, 0.397 kg of perchlorate, 3391 kg of nitrate, 0.57 kg of RDX high explosive compound, and 9.41 kg of organic silicate oil. The 2005 and cumulative total volumes of groundwater and vapor extracted to Site 300 treatment facilities and VOC masses removed are shown in **Table 8-4**.

The central GSA, eastern GSA, and B830-Distal, South treatment facilities discharge to surface drainage courses. The B854-Proximal solar treatment unit/containerized wetland, B815-Distal aqueous phase granular activated carbon, and B830-Proximal, North granular activated carbon treatment systems discharge to an infiltration trench. The other 10 treatment systems discharge to air by misting or to the subsurface using injection wells.

Table 8-4. Volumes of groundwater and soil vapor extracted and masses of volatile organic compounds removed at Site 300 CERCLA Operable Units

Operable Unit		2005		Cumulative total	
Groundwater Treatment	**Startup date**	**Water treated (ML)[a]**	**VOCs removed (kg)**	**Water treated (ML)[a]**	**VOCs removed (kg)**
GSA	1991, 1993	81.7	0.552	1099	20.6
Building 834	1995	0.489	2.36	1.47	34.1
Explosives Process Area	1999	11.8	0.186	39.4	0.586
Building 854	1999	2.60	0.315	20.4	4.56
Pit 6	1998	—[b]	—[b]	0.268	0.0014
Buildings 830 and 832	1999	3.81	0.473	15.5	1.64
Total		100.4	3.89	1176	61.5
Vapor Treatment		**Soil vapor treated (10^3m^3)**	**VOCs removed (kg)**	**Soil vapor treated (10^3m^3)**	**VOCs removed (kg)**
Central GSA	1994	204	0.767	2216.7	66.7
Building 834	1998	730	82.8	2545.7	248
Building 832	1999	94	0.316	436.1	1.86
Building 854	2005	83	1.90	82.9	1.9
Total		1111	85.8	5281.4	318.4

a ML = 1 million liters

b Groundwater treatment is not routine at Pit 6. A hydraulic pump test with a portable treatment unit for TCE removal was conducted there in 1998.

The GSA (OU1) contains maintenance and shop facilities. Dry well and liquid storage activities mobilized contaminants to groundwater. Treatment reduced groundwater influent TCE concentrations to the eastern GSA from 69.5 µg/L in 1989 to 5.5 µg/L in October 2005. Data from July through December 2005 indicate that pumping and treating groundwater from three extraction wells in the Eastern GSA has successfully reduced concentrations of TCE and other VOCs to below their cleanup standard (MCL) of 5 µg/L. Since extraction and treatment activities began at the Eastern GSA in 1991, TCE concentrations in groundwater have decreased from an historical maximum of 74 µg/L to below analytical reporting limits of 0.5 µg/L in groundwater samples from most wells. The number of wells with water containing TCE concentrations exceeding the MCL have decreased from 18 to 0. At the Eastern GSA, LLNL has proposed initiating the "Requirements for Closeout" described in the Remedial Design for the GSA OU (Rueth et al. 1998). These requirements specify that "when VOC concentrations in groundwater have been reduced to cleanup standards, the groundwater extraction and treatment system will be shut off and placed on standby." As required, groundwater monitoring will be conducted to determine if VOC concentrations rise or "rebound" above cleanup standards after extraction ceases. No additional action besides monitoring is anticipated unless VOC concentrations rebound above cleanup standards. TCE concentrations in shallowest groundwater beneath the eastern GSA are shown Figure 2.1-5 of the *2005 Annual CMP Report* (Dibley et al. 2006).

Contaminated groundwater is extracted from eight wells and vapor is extracted from seven wells screened in the Qt-$Tnsc_1$ HSU in the central GSA. Total VOC concentrations in the central GSA have been reduced from 9400 µg/L in 1993 to 473.2 µg/L in July 2005. From 1994 through the end of 2005, total VOC concentrations in the central GSA soil vapor extraction influent stream were reduced from 450 $ppm_{v/v}$ to 11 $ppm_{v/v}$. VOC concentrations in individual central GSA soil vapor extraction wells have also been significantly reduced. Total VOC concentrations in groundwater beneath the central GSA are shown on Figure 2.1-6 of the *2005 Annual CMP Report* (Dibley et al. 2006). TCE concentrations in soil vapor in the central GSA are shown on Figure 2.1-7 of that document.

At Building 834 (OU2), prototype weapons components were subjected to a variety of environmental stresses including heat and pressure. TCE was used as a heat-exchange fluid and was circulated in piping that leaked. There are three HSUs that contain groundwater beneath Building 834. These are, in descending order, the Tpsg, Tps–$Tnsc_2$, and $Tnbs_1$ HSUs. The first two contain contaminants. The maximum 2005 total VOC concentration in groundwater at Building 834 was 190,000 µg/L. This concentration was found in dense claystones of the Tps-$Tnsc_2$ HSU, which underlie the Tpsg HSU. The concentrations in this HSU have remained relatively stable, as no active remediation has been done within the HSU because of the negligible water yields of wells completed in it. Within the Tpsg HSU, which contains the bulk of the TCE in the OU, VOC concentrations in 2005 were a maximum of 58,000 µg/L. Maximum pre-remediation total VOC concentrations in this HSU were 1,060,000 µg/L in 1993. The maxima occurred in the Tpsg HSU within the core area of the OU where, despite pumping and treating of groundwater, VOC concentrations have stayed relatively stable over the last few years. This stability may be the result of continued dissolution of residual free-phase TCE. However, when compared to VOC concentrations prior to active groundwater and vapor extraction, the concentrations are lower. The average TCE concentration within the Tpsg HSU in the core area during 1993 and 1994 was 84,000 µg/L. This has dropped to an average core area TCE concentration of 8000 µg/L in the last two years. Total VOC concentrations in Tpsg-hosted groundwater beneath the Building 834 area are shown on Figure 2.2-3. of the *2005 Annual CMP Report* (Dibley et al. 2006). Groundwater and soil vapor extraction and treatment systems have been operating at Building 834 since 1995 and 1998, respectively. Twelve wells that extract both groundwater and soil vapor compose the extraction network. The groundwater treatment system treats VOCs, nitrate, and organic silicate oil within the shallow Tpsg HSU, and the vapor extraction system treats VOCs within shallow groundwater and the vadose zone. Maximum detected 2005 concentrations of nitrate and organic silicate oil in groundwater at Building 834 were 120 mg/L and 59,000 µg/L, respectively. Maps of the distribution of these two chemicals in Building 834 OU groundwater are shown in Figures 2.2-5 and 2.2-4 of the *2005 Annual CMP Report* (Dibley et al. 2006). Although VOC mass at Building 834 has been destroyed by in situ indigenous bacterial bioremediation, this mass has not been quantified.

At the Explosives Process Area OU (OU4), explosives are pressed and formed. Surface spills from 1958 to 1986 resulted in the release of contaminants at the former Building 815 steam plant. Subsurface contamination is also attributed to explosives wastewater discharges to former unlined rinse-water lagoons. Nine extraction wells in the OU pump groundwater that is treated at six treatment facilities. Construction of two treatment facilities was completed by the September 30, 2005, milestone date. Total VOC, the explosives compound RDX, perchlorate, and nitrate concentrations in $Tnbs_2$ HSU groundwater beneath the Explosives Process Area are shown on Figures 2.4-3, 2.4-4, 2.4-5, and 2.4-6, respectively, of the *2005 Annual CMP Report* (Dibley et al. 2006). Maximum 2005 total VOC concentrations of 51µg/L were detected in groundwater in the $Tnbs_2$ aquifer. The maximum historic total VOC concentration in this HSU was 110 µg/L in a water sample collected in 1992. The total VOC concentrations in source area wells have been reduced by about 40% since remediation began in 1999. RDX concentrations in groundwater have decreased from a maximum of 200 µg/L detected in 1992 to a maximum in 2005 of 91 µg/L. The maximum 2005 concentrations of nitrate and perchlorate in Explosives Process Area OU groundwater were 30 µg/L and 110 mg/L, respectively.

Building 850 (part of OU5) is an explosives firing table. The distributions of tritium, uranium, nitrate, and perchlorate in Qal/WBR and $Tnbs_0/Tnbs_1$ HSU groundwater beneath the Building 850 OU are shown on Figures 2.5-3 through 2.5-10 of the *2005 Annual CMP Report* (Dibley et al. 2006). During 2005, the maximum detected tritium activity in groundwater at the Building 850 OU was 3370 Bq/L (91,000 pCi/L). Monitored natural attenuation (MNA) is the selected remedy for the remediation of tritium in groundwater emanating from the Building 850 area. MNA continues to be effective for tritium in that the extent of the 740 Bq/L (20,000 pCi/L) MCL contour has diminished and receded back towards the firing table source with the highest tritium activities located immediately downgradient of the firing table (**Figure 8-6**). The maximum 2005 total uranium activity in groundwater that contains some depleted uranium was 0.67 Bq/L (18 pCi/L). Total

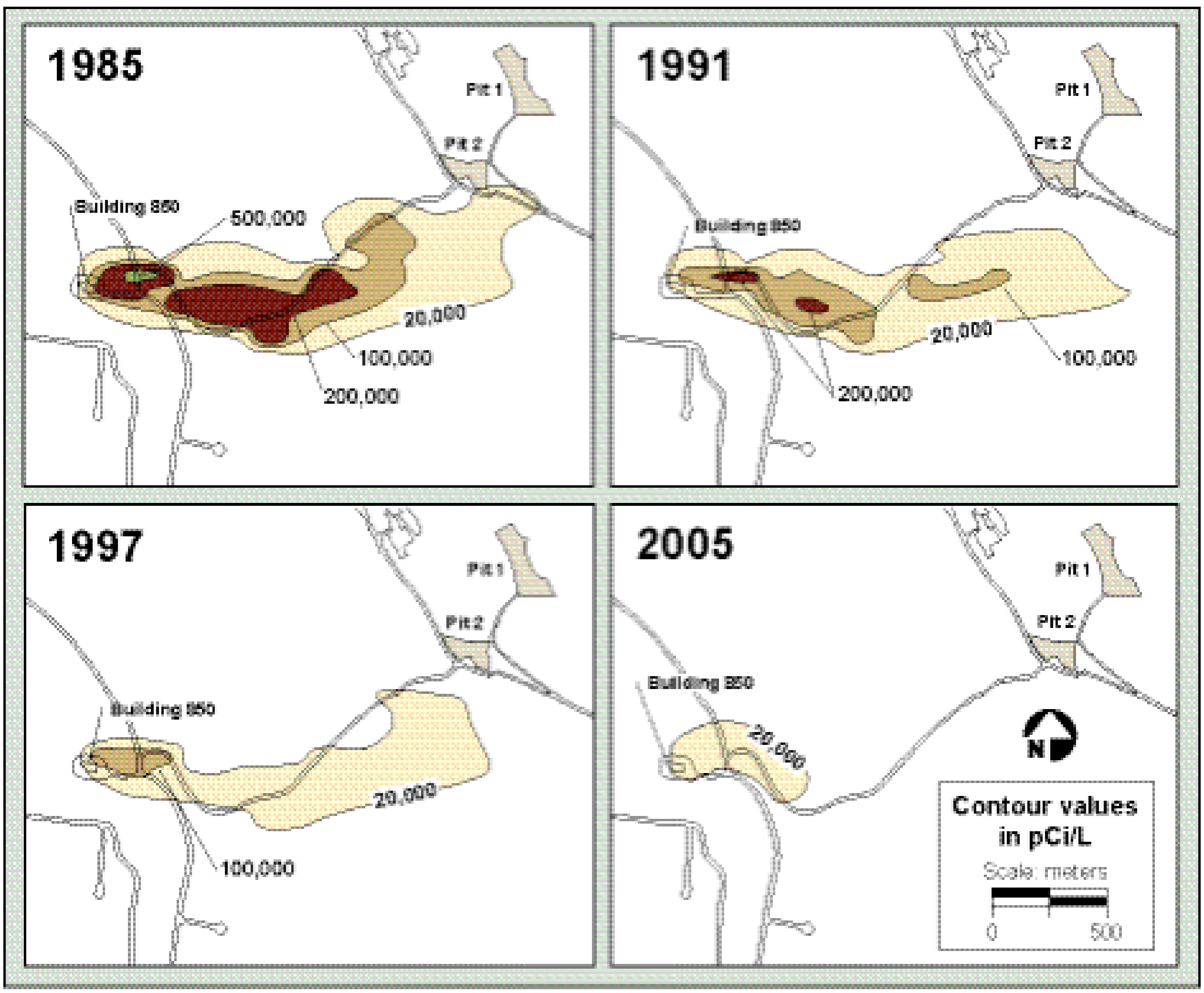


Figure 8-6. Tritium plume in combined Qal and $Tnbs_0$ HSUs during four time periods

uranium activity continues to be below the 0.74 Bq/L (20 pCi/L) state MCL. The maximum nitrate and perchlorate concentrations detected in 2005 in Building 850 OU groundwater were 140 mg/L and 75.2 µg/L, respectively.

Because a number of wells sample groundwater containing perchlorate in excess of the 6 µg/L state Public Health Goal, a remedial strategy for the perchlorate is being developed.

The Building 854 OU (OU6) is another site where weapons components were subjected to mechanical and thermal stresses and where pipes containing TCE leaked. Two extraction wells pump groundwater that is treated at two treatment systems (B854-SRC and B854-PRX) to remove VOCs, nitrate, and perchlorate. A soil vapor extraction system was installed at B854-SRC during 2005 and a treatability test is being conducted to determine if it is a viable method for increasing VOC mass removal at the source area. The 2005 maximum total VOC concentration in groundwater was 180 µg/L, down from a historic maximum total VOC concentration of 2900 µg/L detected in 1997. Maximum 2005 concentrations of perchlorate and nitrate detected in the OU were 15 µg/L and 55 mg/L, respectively. Total VOC concentrations, perchlorate, and nitrate in $Tnbs_1/Tnsc_0$ HSU groundwater beneath the Building 854 OU are shown on Figure 2.6-3, 2.6-4, and 2.6-5 of the *2005 Annual CMP Report* (Dibley et al. 2006).

Pit 6 (OU3) is a landfill that received waste from 1964 to 1973. The landfill was capped and closed under CERCLA in 1997. MNA is the selected remedy for the remediation of VOCs in groundwater emanating from Pit 6. The maximum 2005 groundwater total VOC concentration was 6.4 µg/L and the maximum 2005 groundwater tritium activity was 59 Bq/L (1590 pCi/L). Historic maxima for these two contaminants were 290 µg/L and 127 Bq/L (3420 pCi/L), respectively. The maximum 2005 concentrations of perchlorate and nitrate in Pit 6 groundwater were 6.6 µg/L and 200 mg/L, respectively. The distributions of total VOCs, tritium, perchlorate, and nitrate in groundwater at Pit 6 are shown on Figures 2.3-3 through 2.3-6 of the *2005 Annual CMP Report* (Dibley et al. 2006).

Building 832 Canyon OU (OU7) facilities were used to test the stability of weapons components under a variety of environmental stresses. Contaminants were released from Buildings 830 and 832 through piping leaks and surface spills. Four groundwater extraction and treatment systems operate in the OU to remove VOCs, nitrate, and perchlorate: B832-SRC, B830-SRC, B830-PRXN, and B830-DISS. B832-SRC and B830-SRC extract and treat groundwater and soil vapor. The other two facilities only treat groundwater. Nine extraction wells operate in the OU. The maximum 2005 groundwater total VOC concentration was 8800 µg/L. Maximum VOC concentrations occur in the $Tnsc_{1b}$ HSU. A maximum 2005 total VOC concentration of 1800 µg/L was detected in the Qal/WBR HSU. Total VOC concentrations during 2005 in groundwater from these two HSUs at the Building 832 Canyon OU are shown on Figures 2.7-5 and 2.7-6 of the *2005 Annual CMP Report* (Dibley et al. 2006). Maximum perchlorate and nitrate concentrations detected in 2005 groundwater samples were 12 µg/L and 130 mg/L, respectively. Perchlorate and nitrate concentrations in these HSUs at Building 832 are shown on Figures 2.7-8, 2.7-9, 2.7-11, and 2.7-12 of the *2005 Annual CMP Report*. The *Draft Final Remedial Design for the Building 832 Operable Unit* (Madrid et al. 2005) was submitted ahead of its September 30, 2005, FFA milestone due date (**Table 8-3**). The document described the details of the final remedy for the contamination in the Building 832 Canyon OU. The construction of the B832-SRC treatment facility was completed by its September 30, 2005, milestone date (**Table 8-3**).

The Site 300 Site-Wide OU (OU8) is composed of release sites at which no significant groundwater contamination and no unacceptable risk to human health or the environment is present. For this reason, a monitoring-only remedy was selected for these release sites, which include the Building 801 Firing Table/Pit 8, Building 833, Building 845 Firing Table/Pit 9, Pit 2, and Building 851 Firing Table areas. The results of routine monitoring of these sites are included in Section 2.8 and Chapter 3 of the *2005 Annual CMP Report* (Dibley et al. 2006).

The following sections describe the current status of investigations under way at four sites that are still under investigation and have not yet reached the Record of Decision for a final CERCLA remedy to address environmental contamination. These areas are the Pit 7 Complex, Building 865, the Building 812 Firing Table, and the Sandia Test Site.

Ongoing and Planned Investigations and Cleanup Activities

Pit 7 Complex

The Pit 7 Complex (Figure 5-14) is composed of four landfills—Pits 3, 4, 5, and 7—that received waste from explosives experiments conducted at Site 300 firing tables. Pits 3 and 5 have released tritium to groundwater. Pits 3, 5, and 7 have released depleted uranium to groundwater. The maximum tritium activity detected in groundwater in 2005 in the OU was 14,741 Bq/L (398,000 pCi/L) in the $Tnbs_0$ HSU. The maximum detected total uranium activity in groundwater that contained some depleted uranium was 6.3 Bq/L (170 pCi/L) and was detected in a sample from the Qal/WBR HSU. Perchlorate, TCE, and nitrate also occur in Pit 7 Complex groundwater. Maximum concentrations of perchlorate, nitrate, and TCE detected in groundwater in 2005 were 28 µg/L, 98 mg/L, and 2.6 µg/L, respectively. LLNL submitted the *Final Remedial Investigation/Feasibility Study for the Pit 7 Complex* (Taffet et al. 2005) by the June 27, 2005, milestone date established in the FFA (**Table 8-3**). The report presents details of the hydrogeology, nature and extent of contamination, and risk assessment, and specifies remedial alternatives that can be applied to the contamination.

LLNL submitted the *Draft Proposed Plan for the Pit 7 Complex* by the October 6, 2005, milestone date (**Table 8-3**). This document describes, for the public, the contaminant hydrogeology at Pit 7 and the preferred alternative for final CERCLA cleanup selected by the regulatory agencies and DOE.

Building 865

Building 865 is a former linear accelerator, the Advanced Testing Accelerator. Freon-113 was used as a de-greaser there and has been released to groundwater. The maximum Freon-113 concentration detected in groundwater during 2005 was 300 µg/L. Freon-11 has also been detected in Building 865 groundwater at a maximum 2005 concentration of 1.5 µg/L. The federal and state MCLs for Freon-113 and Freon-11 in drinking water are 1200 µg/L and 5 µg/L, respectively. During 2005, LLNL installed four additional monitoring wells as a part of the remedial investigation of Building 865. LLNL is scheduled to complete a Characterization Summary report detailing the hydrogeology and nature and extent of contamination emanating from Building 865 in 2007.

Building 812 Firing Table

Building 812 is an explosives test firing table. During 2005, a maximum detected groundwater activity of total uranium, in which some of the uranium was due to addition of depleted uranium, was 1.48 Bq/L (40 pCi/L). Prior to the September 30, 2005, due date, LLNL submitted to the regulatory agencies a Characterization Summary report detailing the hydrogeology and nature and extent of contamination emanating from Building 812 (Ferry and Holtzapple 2005a) (**Table 8-3**). A plume of depleted uranium in groundwater and surface soil containing uranium isotopes in excess of Preliminary Remediation Guidelines were identified.

Sandia Test Site

The Sandia Test Site was used in the past for several open air explosives experiments. During 2004, ten boreholes were drilled and soil and rock samples were collected and analyzed for metals and radionuclides. Two of these boreholes were completed as piezometers. Anthropogenic contamination has not been observed in samples of water, soil, or rock collected from the Sandia Test Site. LLNL completed surface soil sampling in advance of the September 30, 2005, milestone date (**Table 8-3**). Prior to the December 15, 2005, due date, LLNL submitted to the regulatory agencies a Characterization

Summary report (Ferry and Holtzapple 2005b) detailing the hydrogeology and nature and extent of contamination emanating at the site (**Table 8-3**).

Environmental Impact

LLNL strives to reduce risks arising from chemicals released to the environment at Site 300 and to conduct its activities to protect ecological resources. At each OU, LLNL proposes a range of remediation options that are applicable for each release site. The option that achieves the goals of reducing risks to human health and the environment and satisfying remediation action objectives, regulatory standards for chemicals in water and soil, and other state and federal requirements is then negotiated by DOE and the regulatory agencies with public input. The agreed upon actions are implemented.

These actions have included groundwater and soil vapor extraction and treatment, source area (lagoon and landfill) capping, monitored natural attenuation, monitoring, and institutional controls.

Groundwater and soil vapor extraction and treatment at Site 300 continue to reduce the mass of contaminants in the subsurface. In 2005, the Site 300 treatment facilities removed approximately 89.7 kg of VOCs, 0.09 kg of perchlorate, 739.7 kg of nitrate, 0.09 kg of RDX high explosive compound, and 0.41 kg of organic silicate oil. Since remediation efforts began in 1990, more than 1176 million liters of groundwater and approximately 5281 million m^3 of vapor have been treated, to yield about 379.9 kg of removed VOCs, 0.397 kg of perchlorate, 3391 kg of nitrate, 0.57 kg of RDX high explosive compound, and 9.41 kg of organic silicate oil.

All ground-disturbing activities, such as well drilling, construction and operation of treatment systems, and groundwater sampling are planned and conducted to minimize disturbance of animal and plant habitat. A biologist inspects all sites and recommendations are made and are incorporated into the plan for each activity. Erosion controls and other recommendations made by the surface water hydrologist are also incorporated into the plans for ground-disturbing activities.